

Aquarius Reflector

Surface Temperature Monitoring

Test and Analysis

Jamie Abbott : JLA Technologies

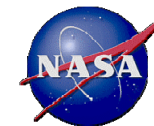


JLA Technologies

Siu–Chun Lee: Applied Sciences Laboratory



**Ray Becker: Jet Propulsion Laboratory,
California Institute of Technology**

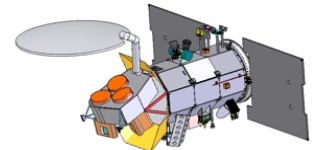


JPL

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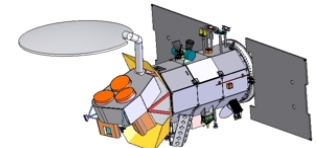


Aquarius Mission Overview



- **Aquarius is a focused satellite mission to measure global Sea Surface Salinity (SSS).**
- **Scientific progress is limited because conventional in situ SSS sampling is too sparse to give the global view of salinity variability that only a satellite can provide.**
- **Aquarius/SAC-D is a space mission developed by NASA and the Space Agency of Argentina, CONAE.**

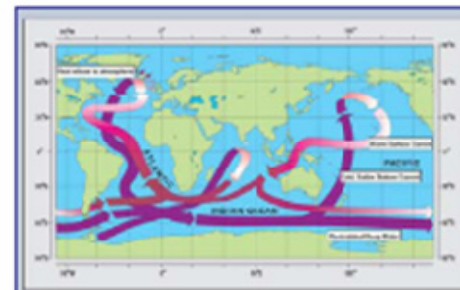
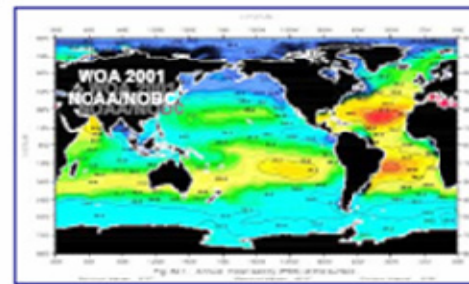
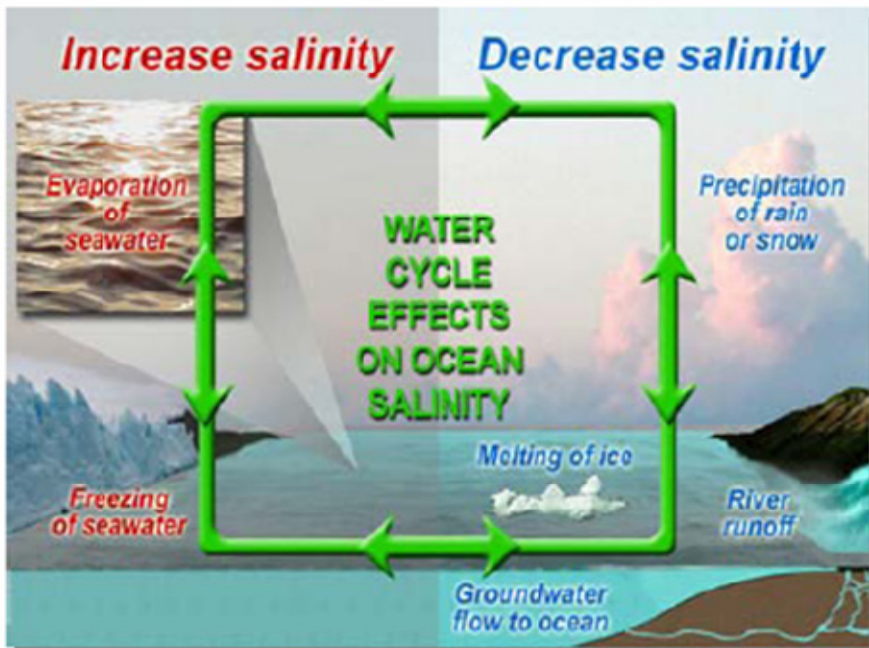
Surface Sea Salinity (SSS) from Aquarius



Understanding the Interactions Between the Global Water Cycle, Ocean Circulation and Climate

Salinity links the climatic variations of the global water cycle and ocean circulation

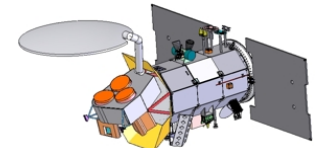
- Salinity is required to determine seawater density, which in turn governs ocean circulation.
- Salinity variations are governed by freshwater fluxes due to precipitation, evaporation, runoff and the freezing and melting of ice.



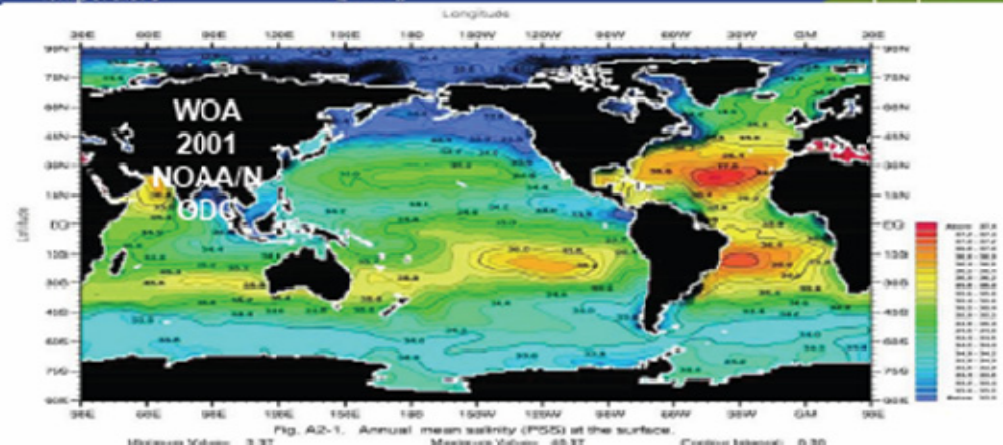
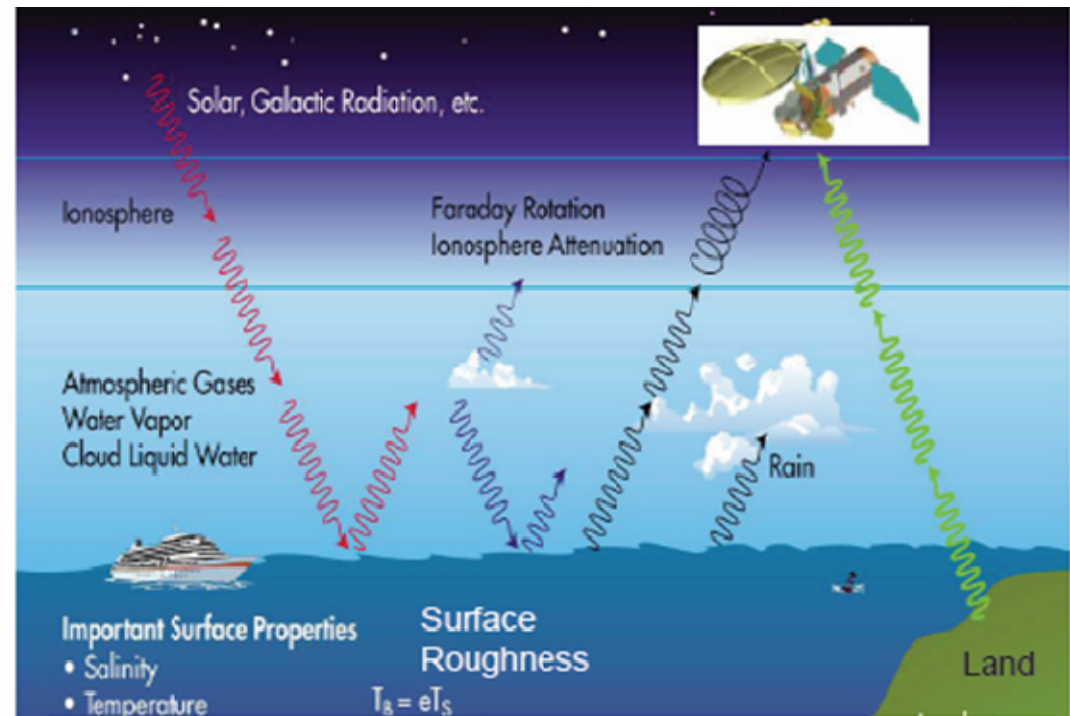
Benefits from Aquarius

- *Discovery*
- *Exploration*
- *Climate prediction*
- *El Niño forecasts*
- *Global Water budget*
- *PATHFINDER: Proof-of-Concept for future missions*

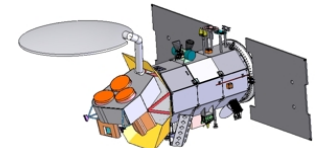
Aquarius Mission



- Aquarius retrieves salinity by measuring sea surface brightness temperature by using a very stable radiometer in L-band.
- The biggest error to this measurement is due to the sea surface roughness.
- A co-pointing L-band scatterometer is used to accurately measure the sea surface roughness (to be removed by ground processing)
- The spacecraft is built by CONAE (Argentina)
- The radiometer built by GSFC
- Remainder of instrument built/managed by JPL

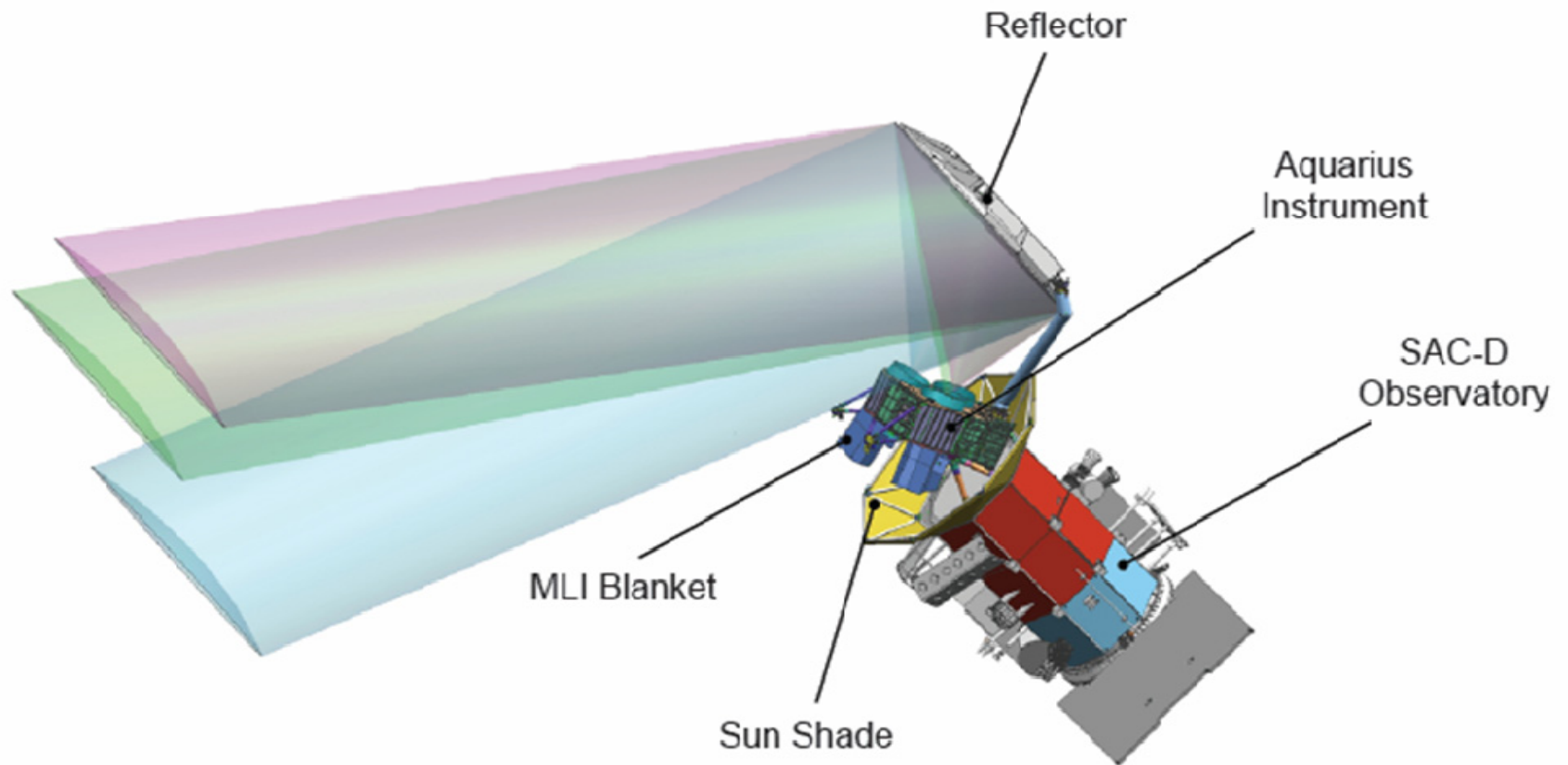
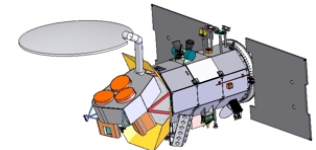


Key Thermal Requirement: Reflector Temperature Monitoring

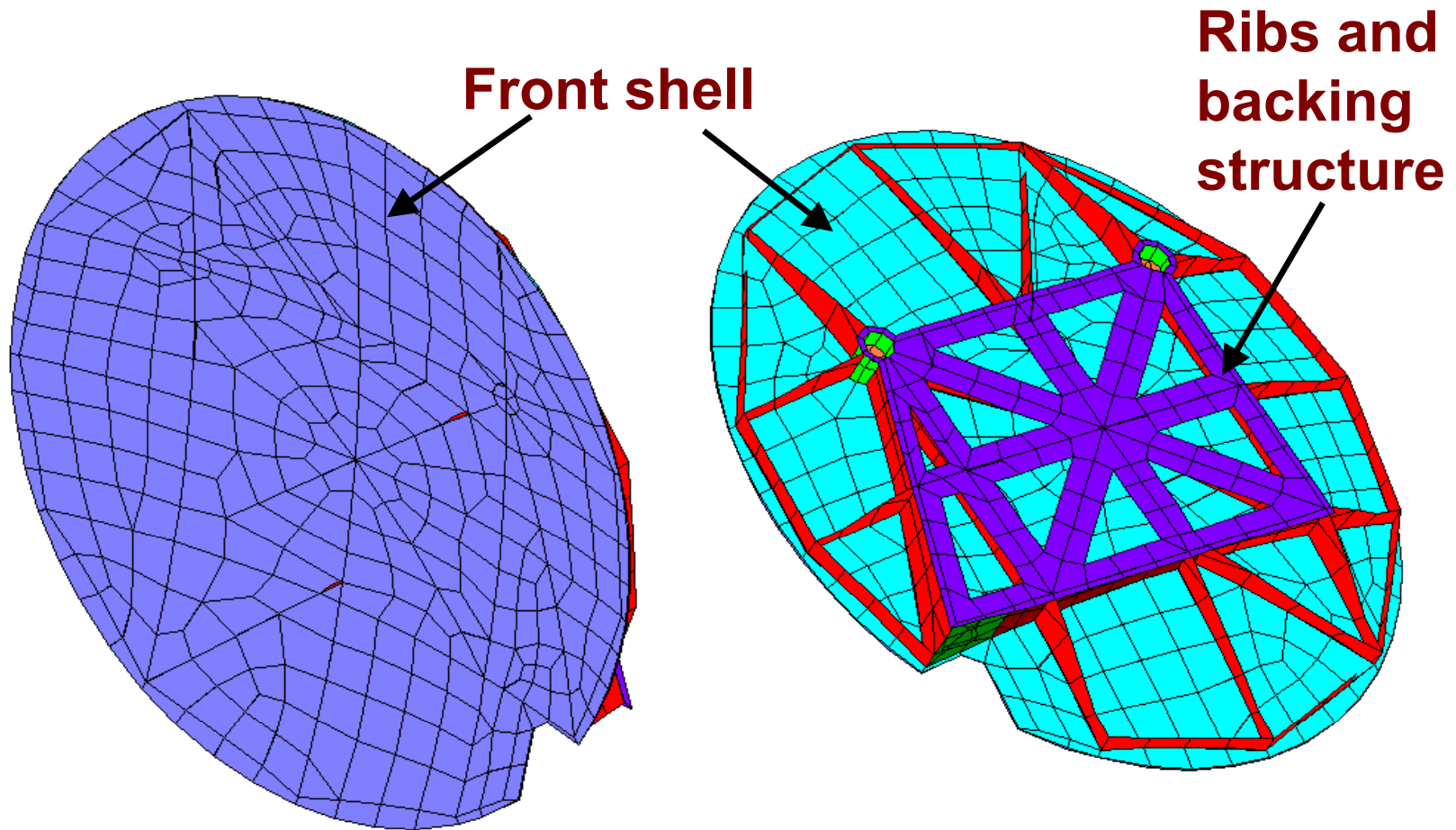
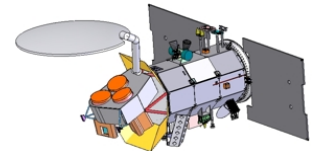


- Temperature sensors shall be placed on the reflector structure such that the temperature of the reflector's front surface in the vicinity of the sensor can be determined to an accuracy of $\pm 3^{\circ}\text{C}$
- Reflector average front surface temperature knowledge will be used along with knowledge of the reflector front surface emissivity vs. temperature to compensate for energy emitted by the reflector in the L-band (1.4 GHz)

Spacecraft Overview



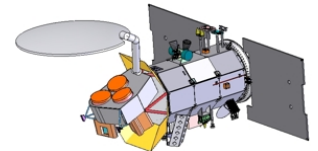
Aquarius Reflector



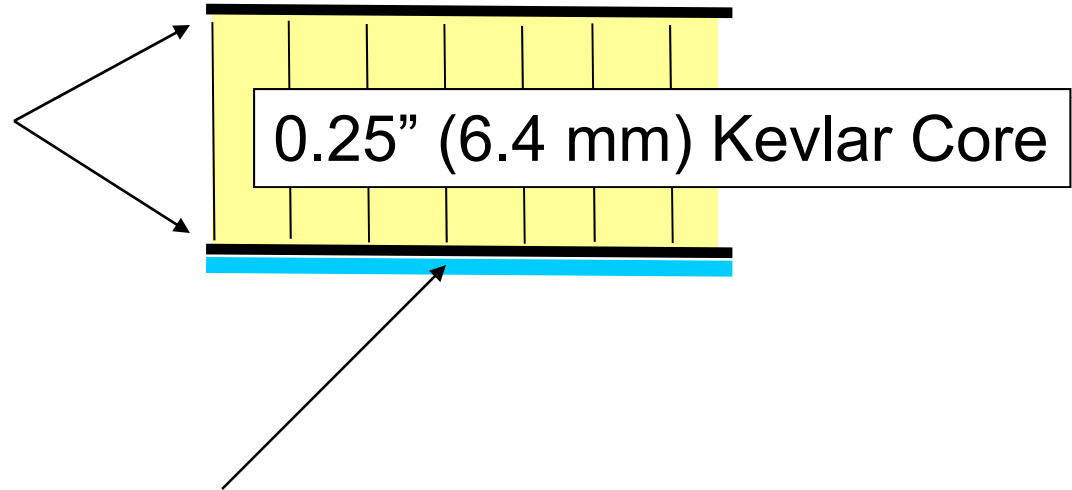
**View of
Reflector Front**

**View of
Reflector Rear
(MLI not shown)**

Reflector Front Shell Honeycomb Panel Construction

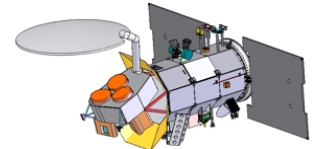


0.01" (0.25 mm)
Graphite/Cyanate Ester
Facesheets

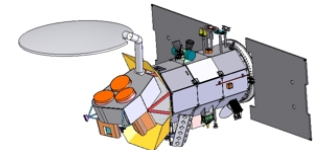


VDA and White Paint on front surface

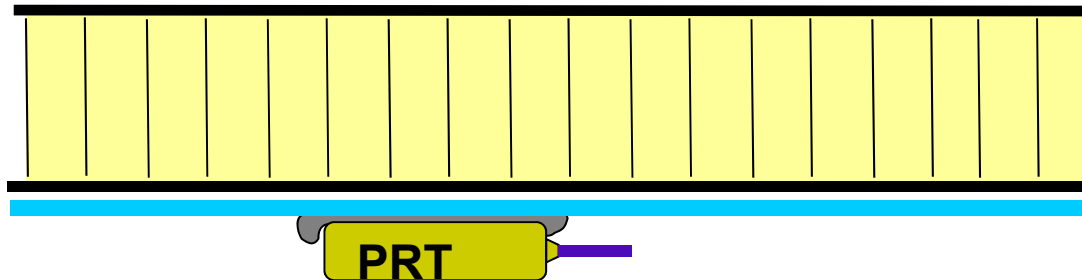
How Do We Measure Reflector Surface Temperature?



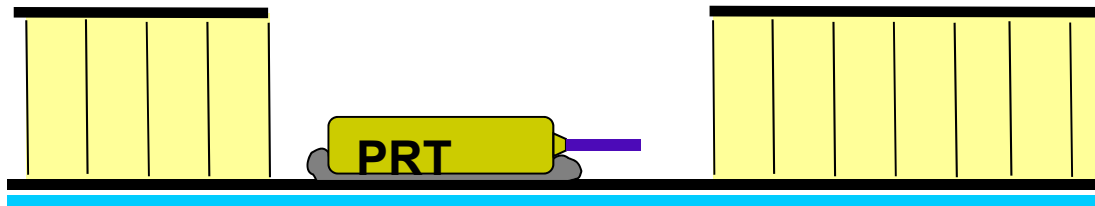
- **PRT selected for temperature sensor**
 - Pros: Good accuracy with individual calibration curve
 - Cons: Heavy, Requires shielding (additional mass)
- **Location options**
 - Reflector front facesheet, front surface
 - Reflector front facesheet, rear surface
 - Reflector rear facesheet



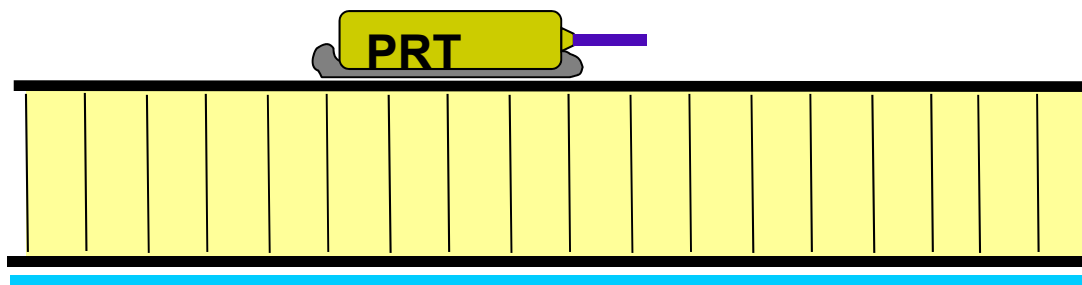
Location Options



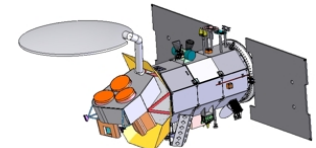
Bad for science mission



Requires delicate honeycomb removal

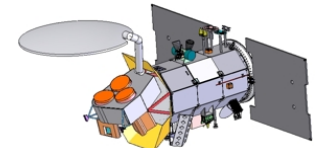


**Option selected:
Rear facesheet**



PRT on Rear Facesheet Issues

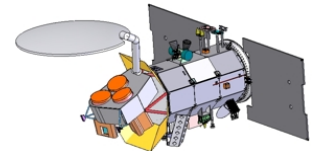
- **We want to measure the front facesheet temperature**
- **PRT is separated from the front facesheet by the Kevlar honeycomb**
 - Low thermal conductivity of honeycomb creates ΔT between PRT and front facesheet
 - Delta T can be as high as 10°C
- **PRT and associated wires and shielding are relatively massive as compared to the lightweight honeycomb panel**
 - Induces time-lag in PRT temperature response
- **How do we compensate for the ΔT and time-lag?**
 - Test and analysis



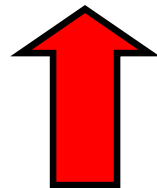
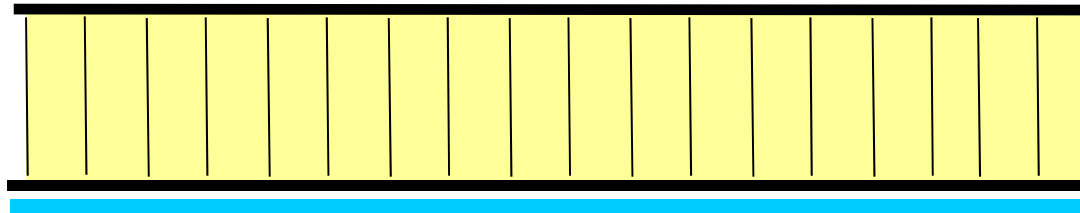
PRT Panel Thermal Test

- Representative honeycomb panel manufactured using flight-like materials and processes
- PRT mounted to rear of panel using flight-like materials and processes
- Panel tested in ASL's thermal vacuum chamber
- Test data used to validate thermal model
- Thermal model used to develop compensation method

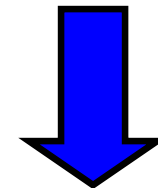
Reflector Schematic



MLI Blanket

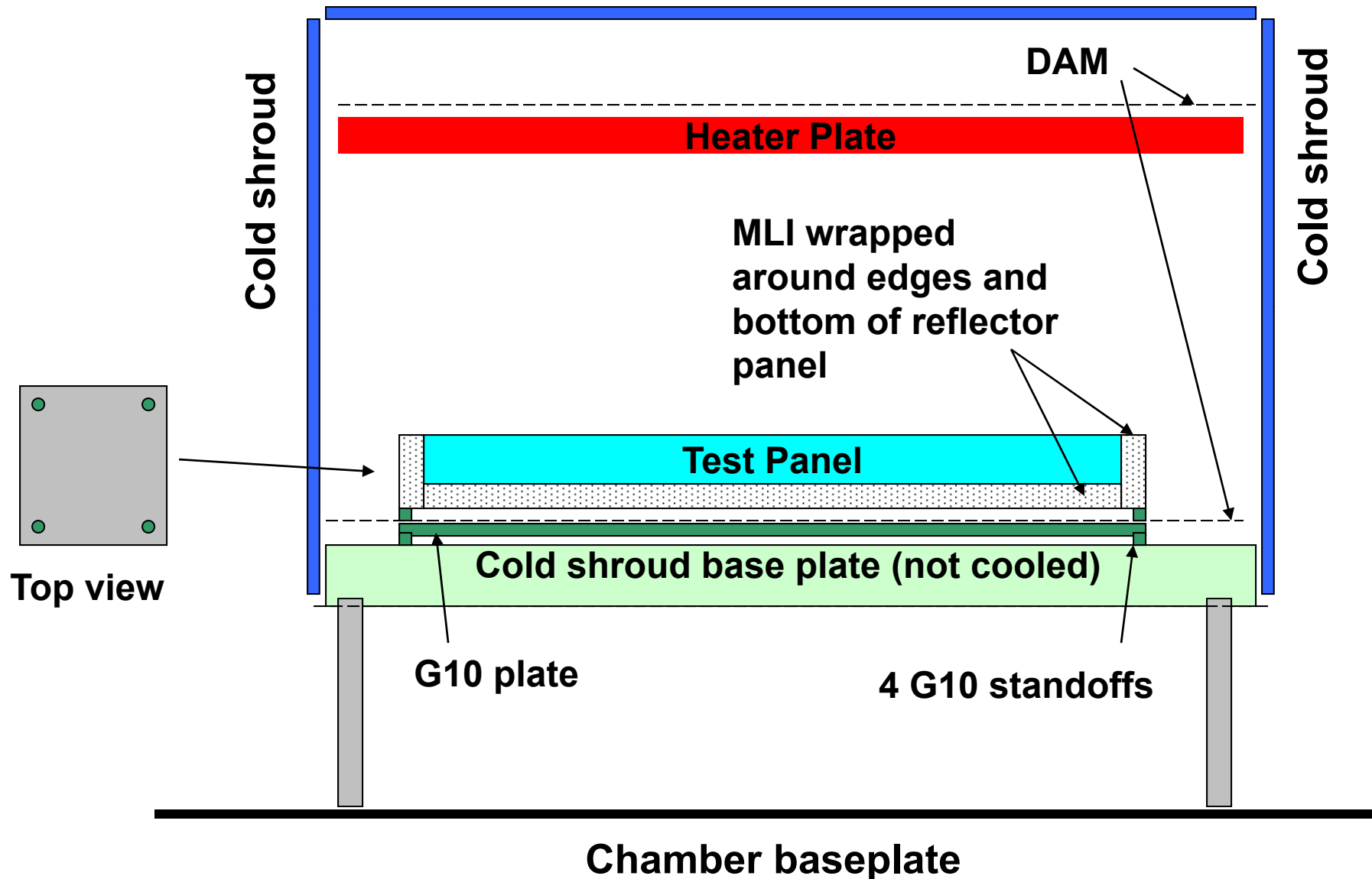
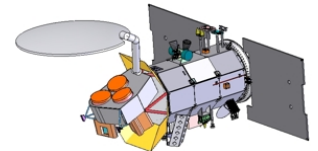


**Solar, Earth IR
and Albedo**

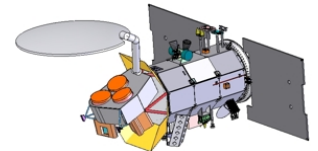


**Radiated
Heat Out**

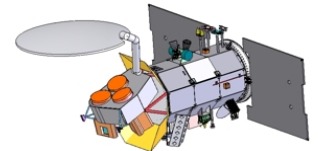
Test Setup Schematic

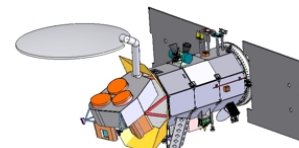


ASL Thermal Vacuum Chamber



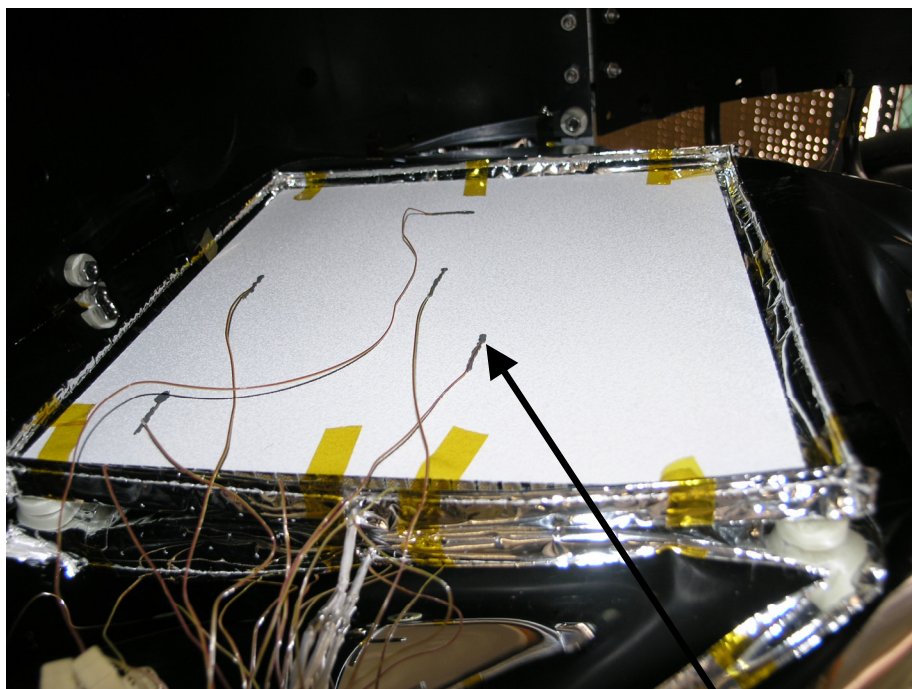
Test Panel in Chamber





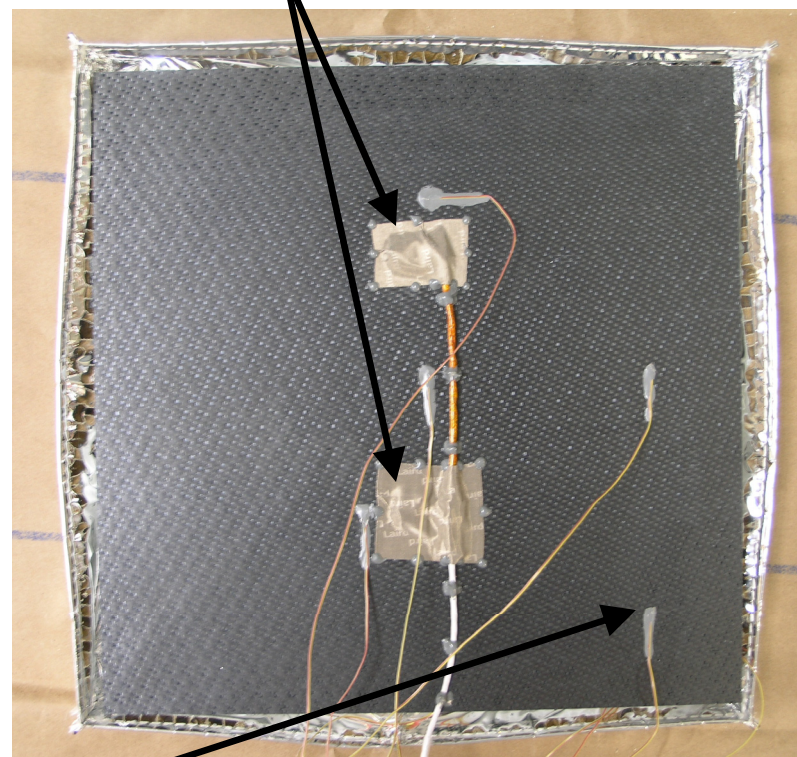
Instrumented Test Panel

PRT Installation

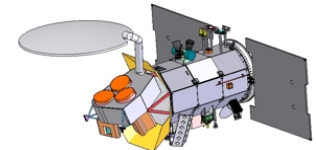


In Chamber

T/C

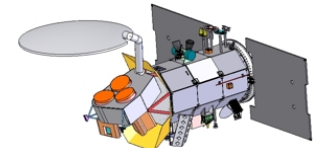


Rear Facesheet

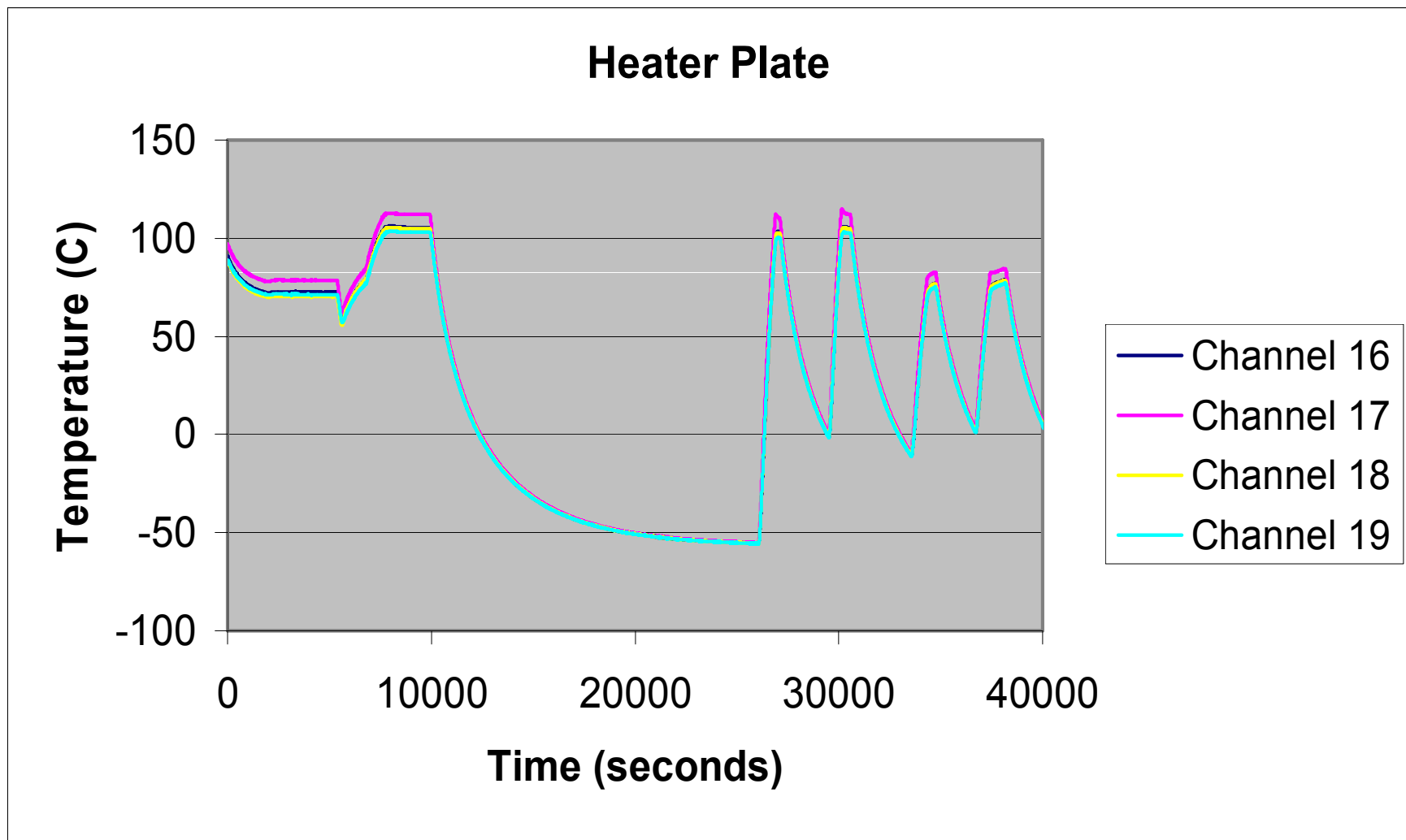


Test Procedure

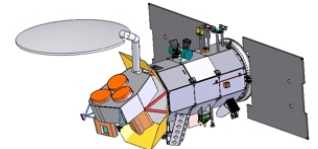
- Shrouds cooled
- Heater plate turned on
- 2 steady state conditions then transient condition run
- Heater plate turned off – temperatures allowed to cool to -55°C
- Heater plate cycled on and off to simulate reflector coming into and out of Sun



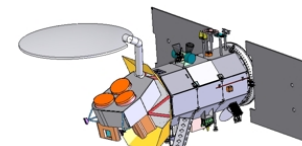
Test Temperature Profile



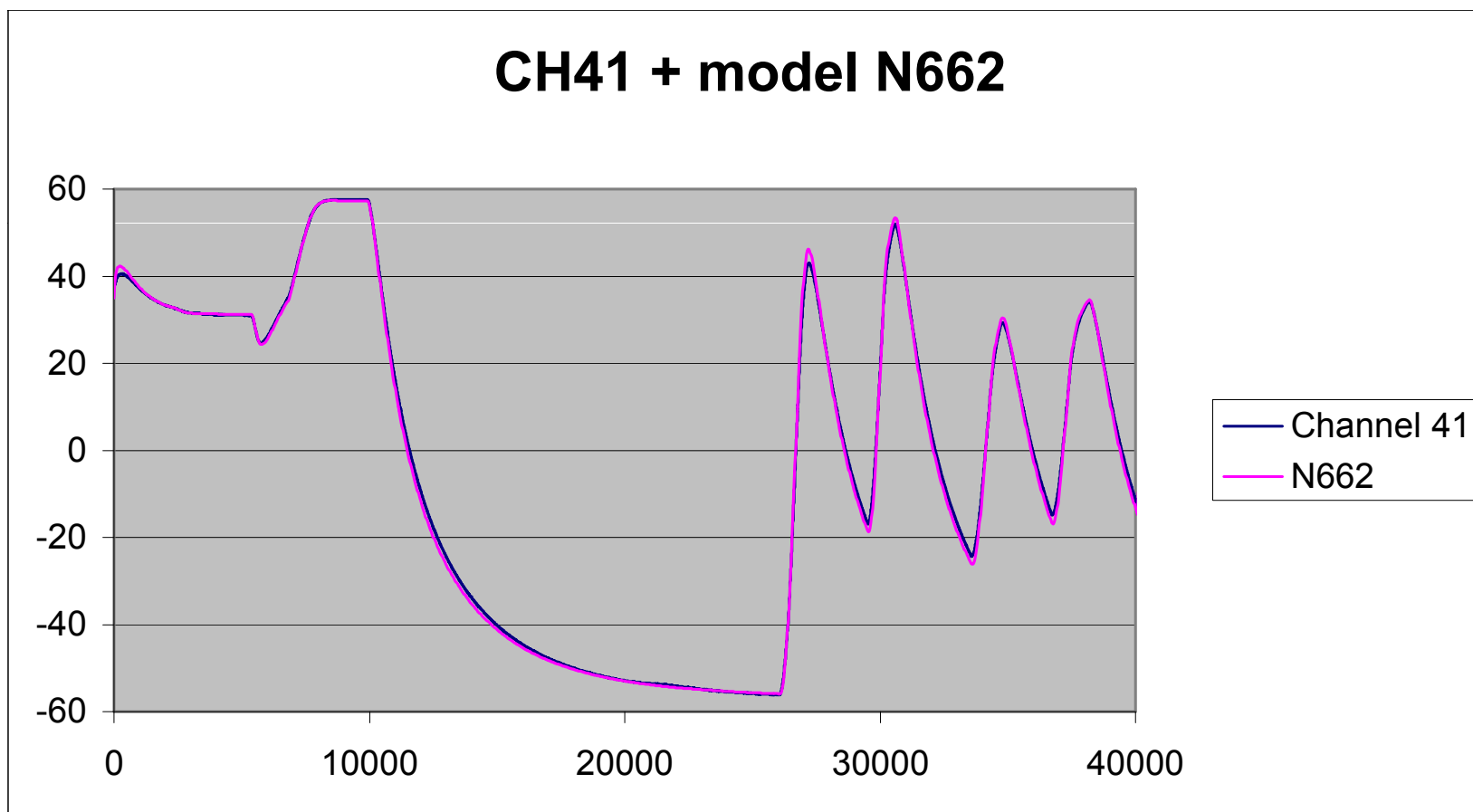
Thermal Model Correlation



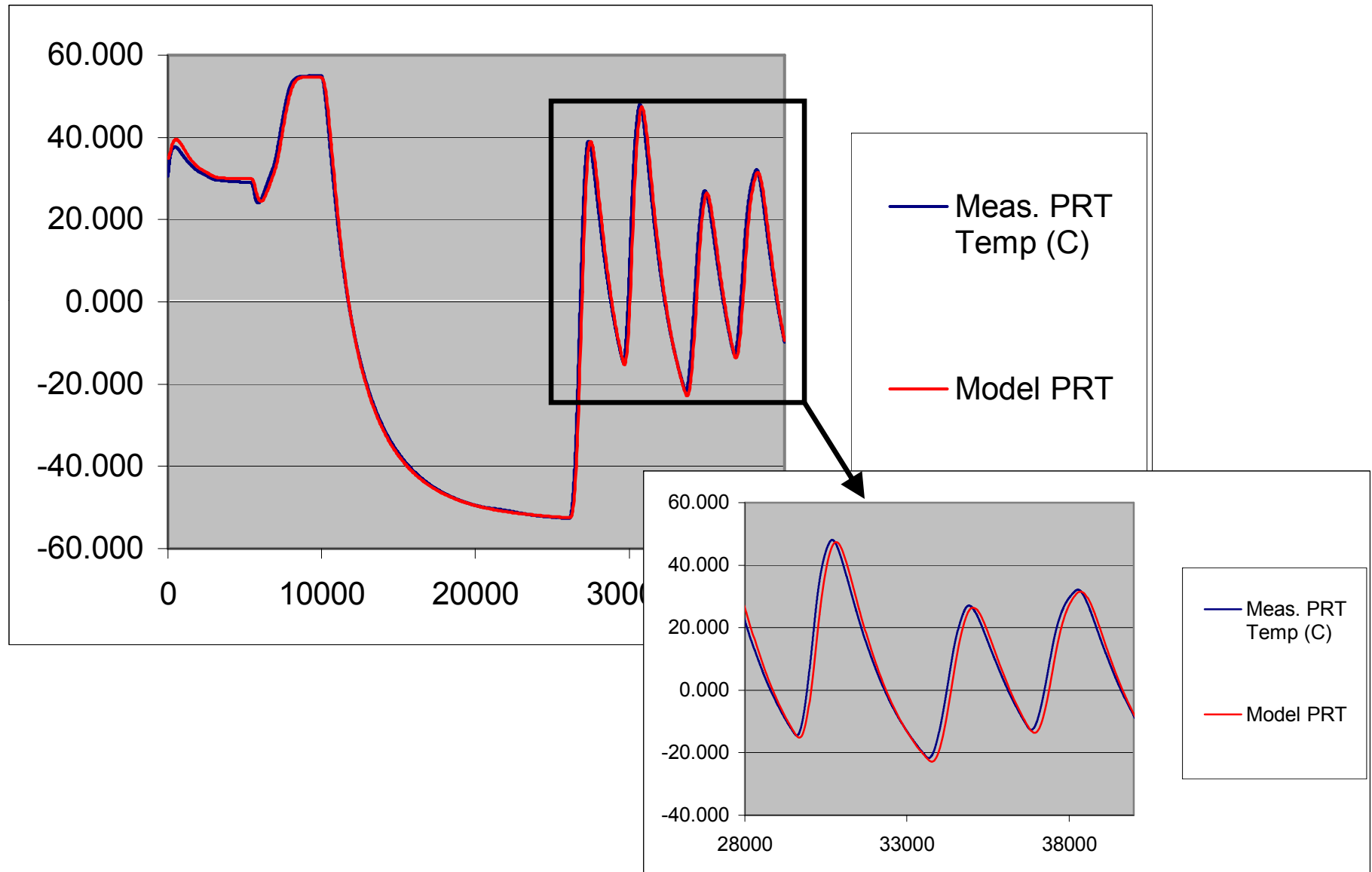
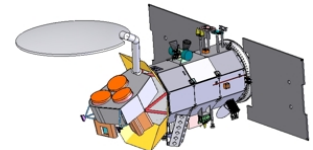
- **Thermal model built of chamber and test panel**
 - SINDA/3D
 - TSS
- **Model run for test conditions**
 - Heater plate and shroud temperatures input into model
- **Test panel temperatures compared to test data**
 - Good correlation achieved
- **Minor model modifications**
 - Heater panel height changed from 8" to 7.87" (20.3 cm to 20.0 cm)
 - Additional conductance added to represent 24 gauge PRT wires



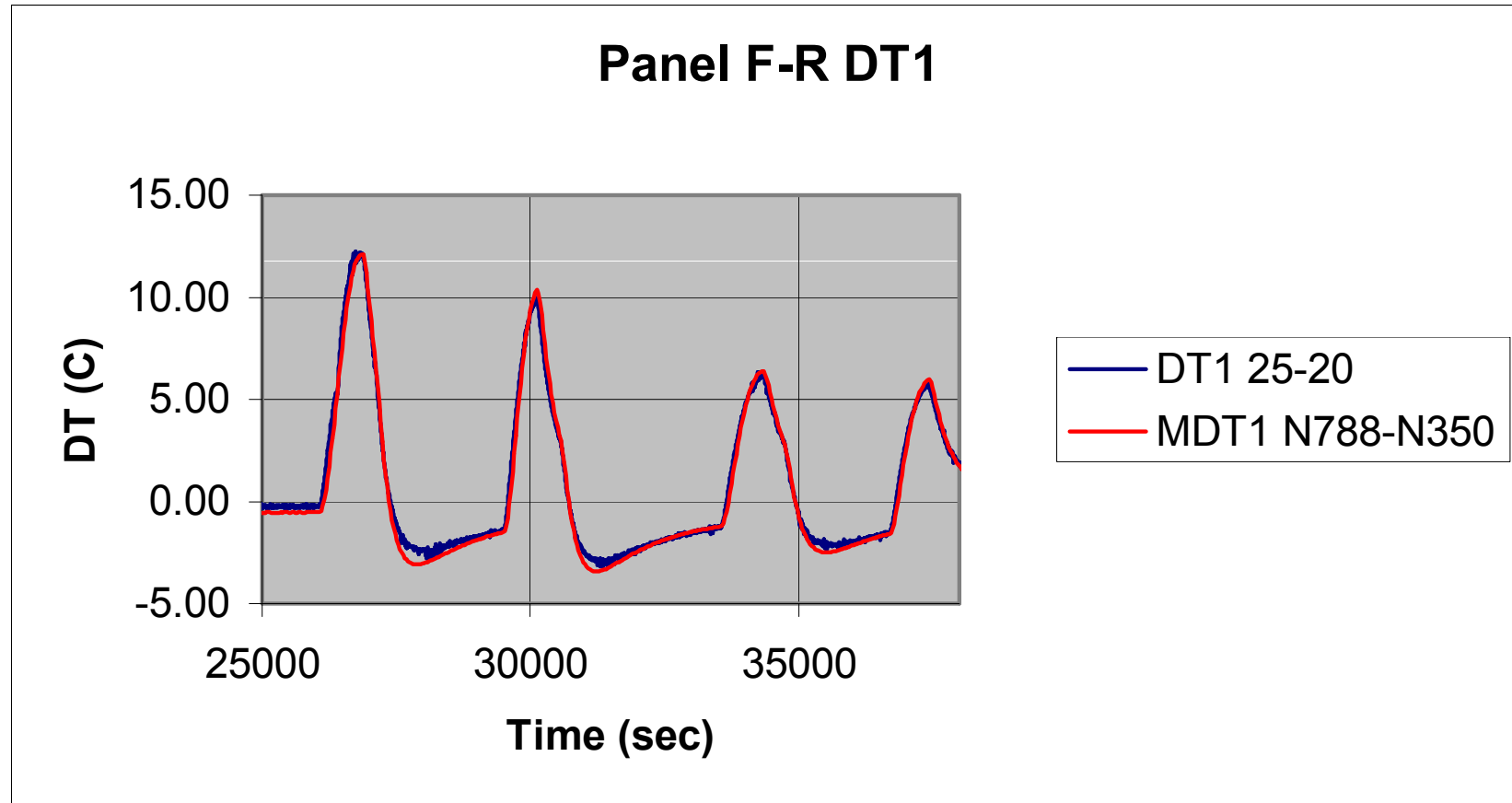
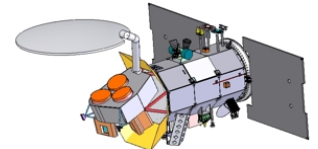
Model Correlation: Panel Front



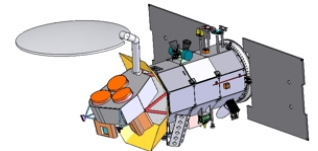
Model Correlation: PRT



Model Correlation: Panel Front-Rear ΔT



Compensation Method

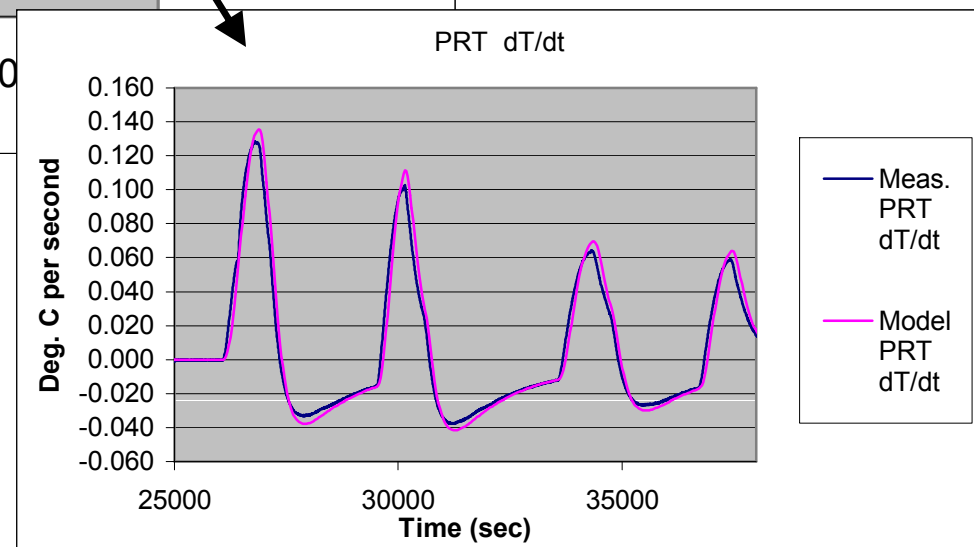
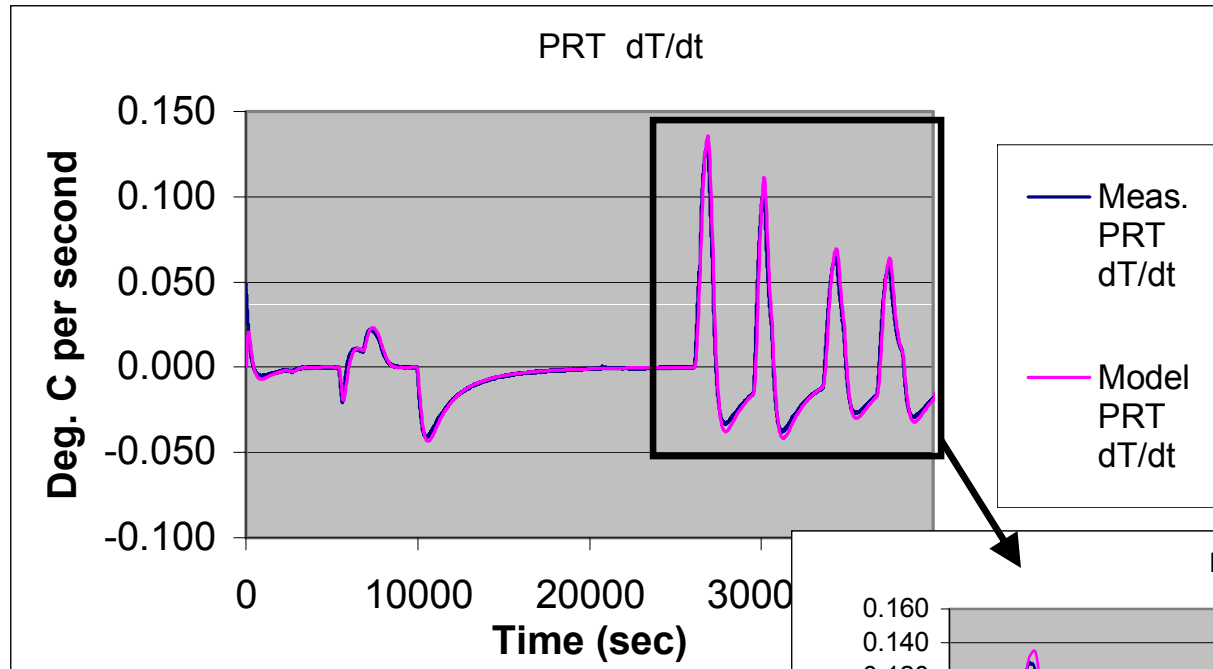
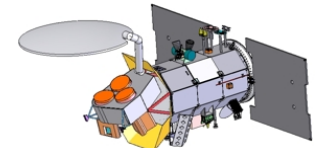


- During on-station operation, we will have access to the PRT measurements
- We need to develop a method that takes the PRT readings and converts them to front facesheet temperatures
- One way to do this is to use the PRT measurements along with the 1st and 2nd time derivatives according to the equation:

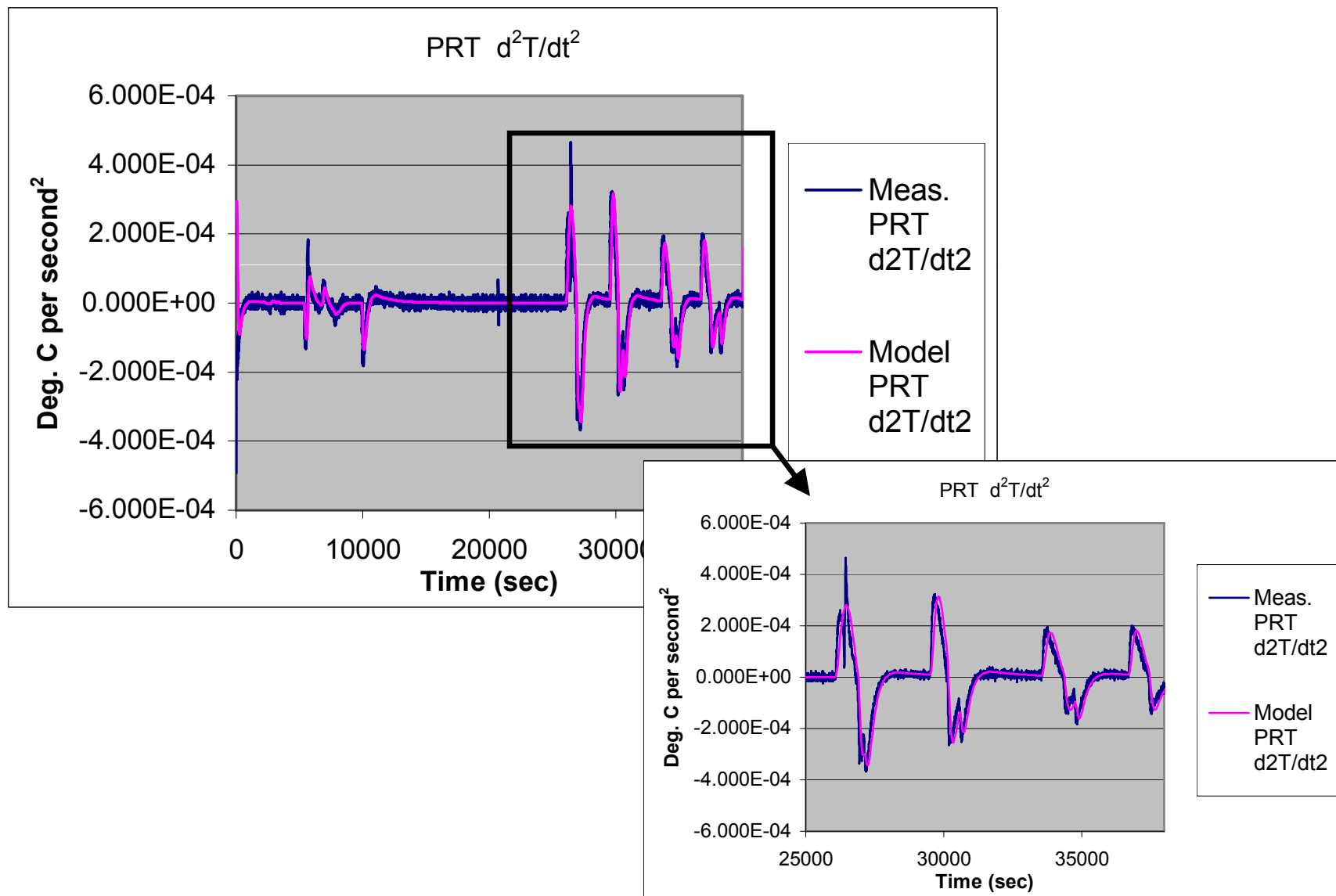
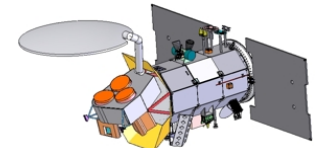
$$T_C = T_M + K_1 * dT_M/dt + K_2 * d^2T_M/dt^2$$

- Where:
 - T_C = Compensated PRT Temperature (°C)
 - T_M = Measured PRT Temperature (°C)
 - dT_M/dt = First derivative of the measured PRT temperature with respect to time (°C/second)
 - d^2T_M/dt^2 = Second derivative of the measured PRT temperature with respect to time (°C/second²)
 - K_1 and K_2 are constants with units of seconds and seconds² respectively

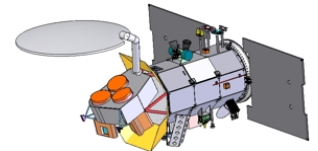
PRT DT/dt Comparison: Good



PRT D^2T/dt^2 Comparison: Good

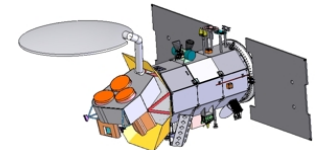


How do we determine the accuracy of the compensation method?



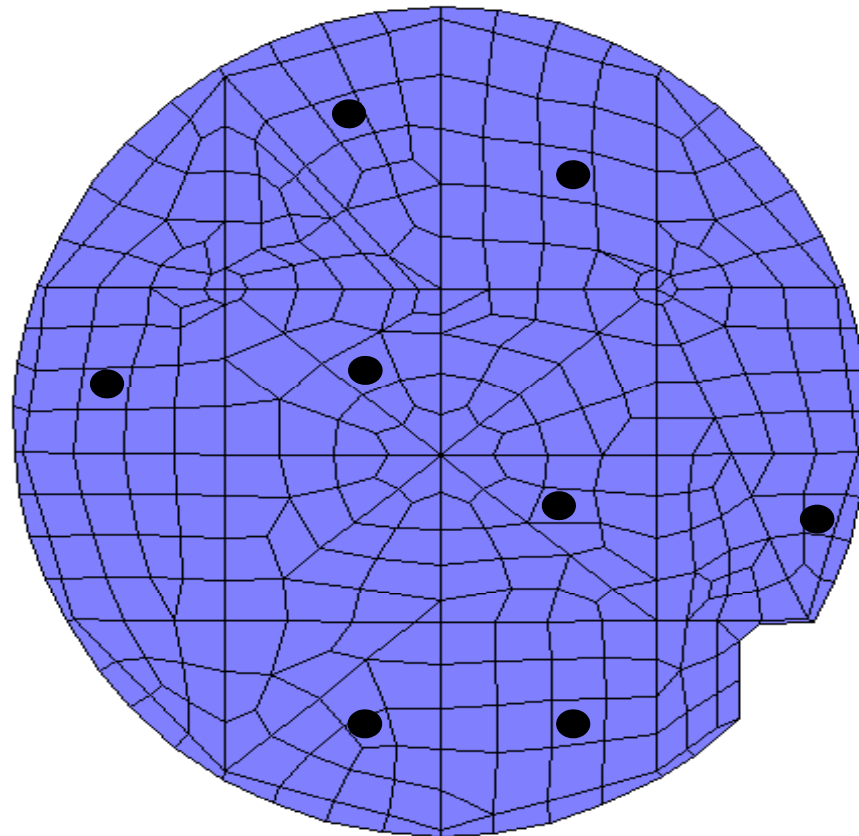
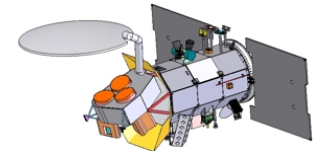
- **Constants K_1 and K_2 determined to give good front facesheet temperatures based on PRT readings during test**
- **Determine how compensation method works for operational conditions**
 - Detailed panel thermal model integrated with full reflector and spacecraft thermal model
 - Integrated model run for a variety of operational conditions
 - PRT temperatures (from model) compared to corresponding front facesheet temperatures (from model) to determine method accuracy

Operational Conditions Used For Compensation Method Evaluation

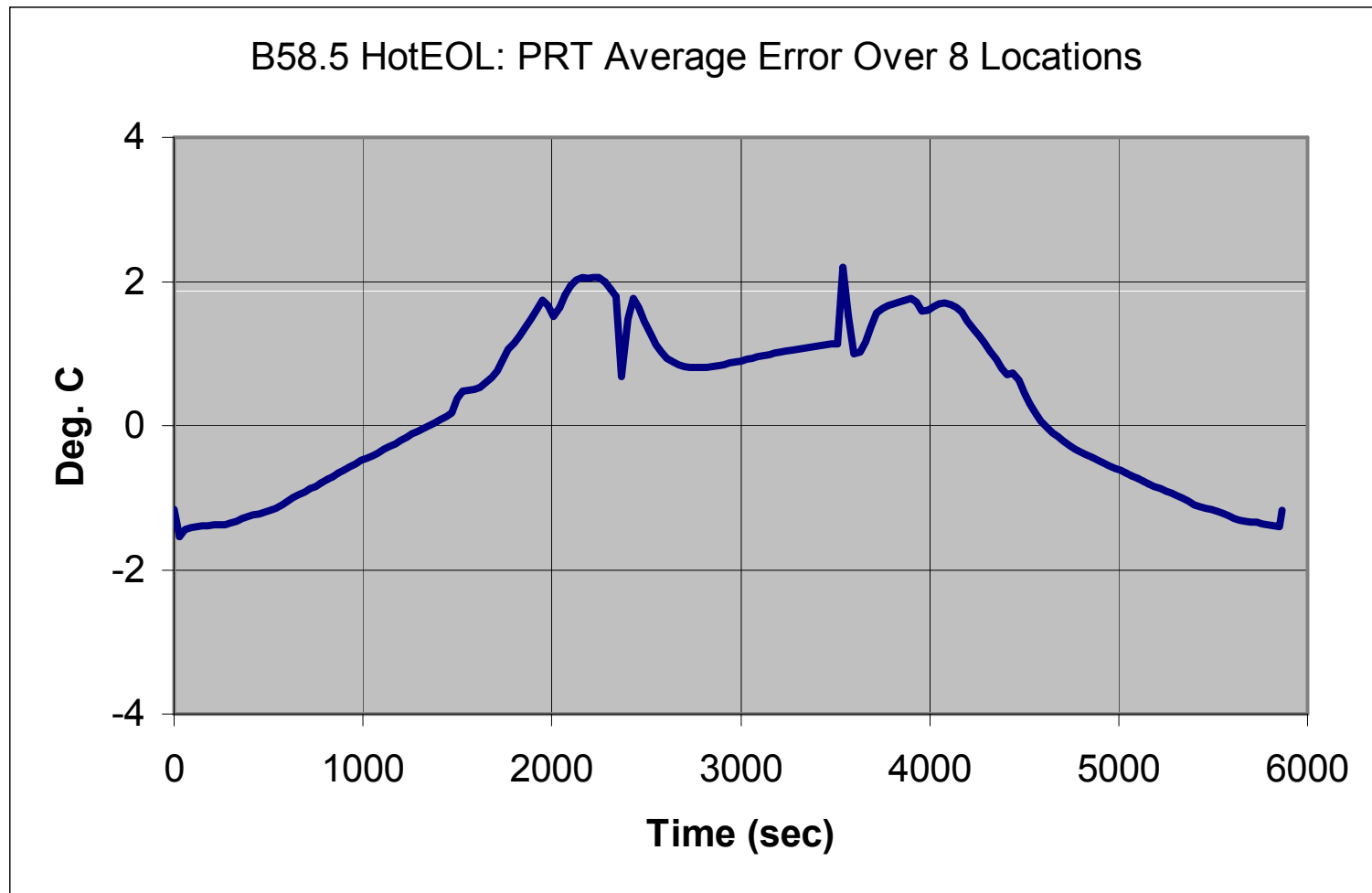
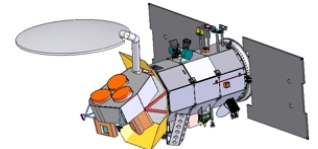


Orbital Condition Name	Beta Angle (degrees)	BOL / EOL	Hot / Cold Environmental Constants Used
(1) B58p5HotEOL	58.5	EOL	Hot
(2) B58p5ColdBOL	58.5	BOL	Cold
(3) B70HotEOL	70	EOL	Hot
(4) B80HotEOL	80	EOL	Hot
(5) B90HotEOL	90	EOL	Hot

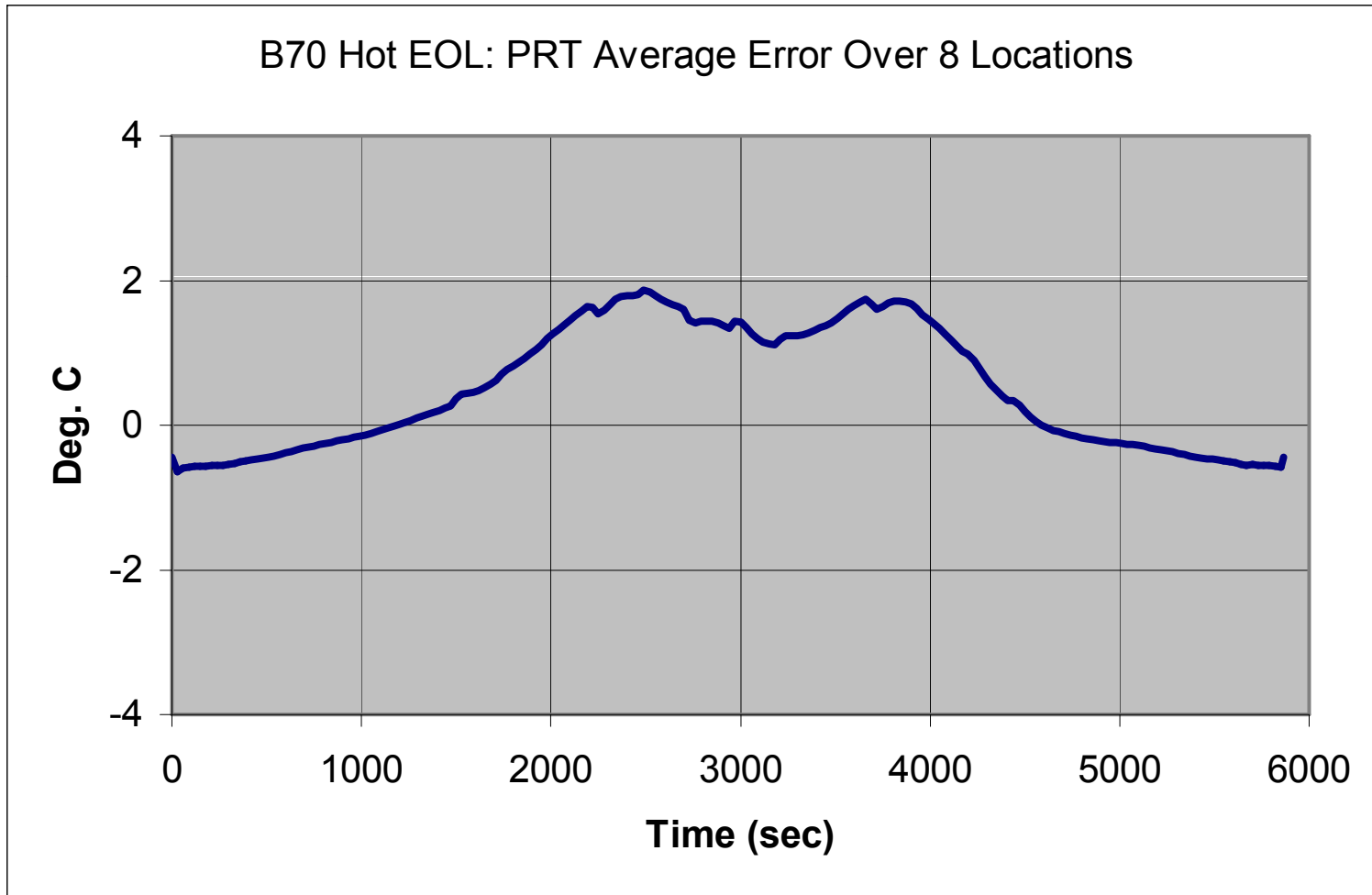
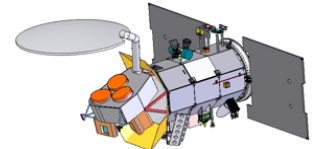
Reflector Positions Used to Study PRT Compensation Method



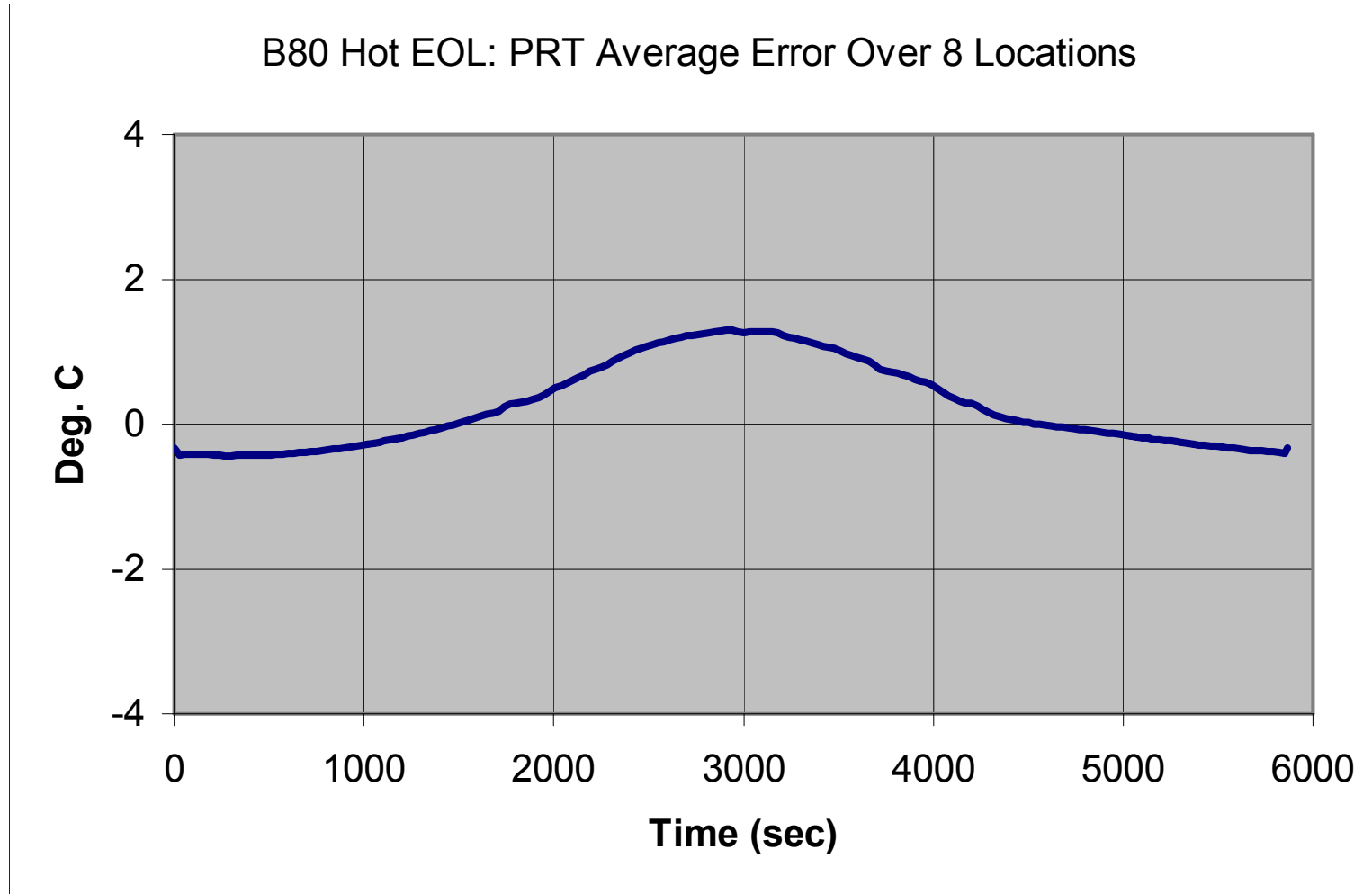
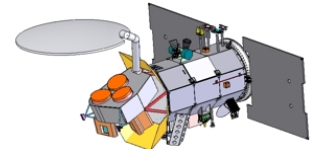
Front Surface Average Temperature Knowledge Error: B58p5HotEOL

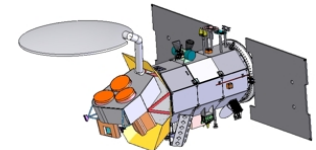


Front Surface Average Temperature Knowledge Error: B70HotEOL



Front Surface Average Temperature Knowledge Error: B90HotEOL





Conclusions

- **The Aquarius reflector will have PRTs mounted to the rear facesheet of the front shell**
- **A thermal test was performed to study the error induced by the mounting method**
- **A method has been developed to use the PRT readings to calculate the reflector front facesheet temperature within 3°C**